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Neonate mortality in captive Asian elephants (*Elephas maximus*)

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Abstract

One third of Asian elephants born in European zoos and circusses are stillborn (16.0%) or killed or refused by their mothers (15.7%). Stillbirths and infanticides are rare in extensively kept and wild-living elephants. Infanticide could be related to life history of the mothers: Females which had grown up in the company of an older, motherly female adopted their offsprings without complications. Those having lacked such affection, tended to kill or at least not to adopt their neonates. Stillborn calves show higher neonate weights (124.6 ± 20.8 kg) than surviving calves (92.0 ± 27.6 kg). Positive correlations were found between gestation period and neonate weight as well as between neonate weight and relative weight (body weight/shoulder height) of the mother. As female elephants in modern zoos and circusses are relatively heavier than those living in Asian camps, they produce calves after longer gestation periods (644.4 ± 19.5 days) with larger neonate weights (105.6 ± 26.6 kg) than extensively kept females in Asia (598.1 ± 51.6 days; 74.0 ± 21.6 kg). Chances to survive parturition are negatively correlated with lenght of gestation and neonate weight.

Introduction

The reproduction rate of Asian elephants kept in western zoos and circusses is very low as compared to that in extensively kept working elephants in South Asian camps due to low availability of reproducing bulls, relative short reproduction periods in females and high mortality of neonates (Kurt 1995 b). Between 1902 and 1992, 44 out of 121 Asian elephants born in Europe were stillborn or died before reaching the age of one year. This infant mortality of 36.4% is more than five times higher than the infant mortality (7%) in wild-living populations of Sri Lanka (Kurt 1974) and South India (Sukumar 1992) or in extensively kept working elephants in Myanmar (Burma) (Toke Gale 1974; Kurt 1995 a).

High neonate mortality in zoo and circus elephants is due to infanticide by the mothers and stillbirths, respectively. Aggression of mothers towards neonates has been rarely reported in wild-living and extensively kept Asian elephants. On the contrary, numerous reports mentioned adoption of neonates and even suckling by females other than the mother (Kock 1994; Nair et al. 1992; Toke Gale 1974). Not all these females adopting neonates had previously experienced the successful raising of its own calf, however, not all captive females show adopting behaviour (e. g. Kock 1994; Weilenmann and Isenbügel 1992). Hence, it is reasonable to assume that presupposition for maternal behaviour is established under certain conditions already at a neonate or juvenile age. Therefore, the first hypothesis of this study reads: Females having experienced motherly affections as neonates and juveniles more readily accept their own offsprings than females lacking such affection, when they come in a zoo or circus already as young animals.

Certain females are known to establish "special relationship" independent of rank and ages leading to the well-known phenomenon of allo-mothers or "aunts" (Garaï 1992), and it is known that "aunts" are paramount before, during and after parturition to calm the parturating female and secure the life of the neonate. It can be assumed that such special relationships are established only after a certain timespan and that females shifted from one zoo to another are less engaged in special relationships than females which always lived in only one establishment with relevant female partners available. Therefore, the second hypothesis reads: Shifted females parturate less and raise their offsprings less successfully than females which always lived within one and the same group.

Premature stillbirths of underdeveloped calves are rarely reported from wild-living and captive Asian elephants, and occur either in connection with capturing operations (Dittrich 1967; Kurt 1992) or twin-births (Toke Gale 1974), but never in connection with social distress. Hence, the third hypothesis states that stillbirths are not related to processes of socialization but to physical characteristics of the mother.

It is generally agreed upon that captive elephants are heavier than wild-living ones of the same shoulder height, and that females kept in zoos and circuses are relatively heavier than female working elephants in Asian camps (Benedict 1936; Kurt and Nettasinghe 1968; Sukumar et al. 1988; Kurt 1995 a). The fourth hypothesis of this study therefore reads: Neonate mortality is positively correlated with the relative weight of females (body weight/shoulder height).

Material and methods

Data were collected on 48 neonate elephants in modern zoos and circuses in Europe, the U.S.A. and Japan (Anghi 1962; Dittrich 1967, 1977; Knie pers. com.; Kock 1994; Kock pers. com.; Lang and Eggenberg 1991; Prins 1992; Reuther 1969; Rietkerk et al. 1993; Turkington 1991; Weilenmann and Isenbügel 1992) and on 21 calves born in South Asia (Deraniyagala 1995; Krishne Gowda 1969, 1971; Ratnasooriya et al. 1991; Sanderson 1907; Toke Gale 1974). Data from the zoos of Myosore (south India) and Dehiwala (Sri Lanka) have been included in those from Asian camps, since these elephants live under similar conditions as traditionally kept working elephants (Tab. 1).

Gestation periods are given in days and are considered to last from the last successful mating up to parturition. It is assumed that mating was successful when insertion of the penis to the vagina, evidence of exudation of seminal fluid from the vagina following dismount and resting of the male after dismounting were observed (see Poole 1989).

Neonate weights are given in kg. Shoulder height represents the height at the withers in cm. Fore some pregnant females relative body weight was calculated as the body weight (kg) divided by shoulder height (cm). For these females shoulder height was measured with a device when they were standing on all four legs. The results were rounded off to the nearest 10 cm. They were weighed on heavy-duty weight-bridges, and the results rounded off to the nearst 100 kg. In Carl Hagenbeck's Tierpark (Hamburg), the Swiss National Circus Knie and the Zoo in Zürich, elephants are regulary weighed and measured. It was therefore possible to obtain accurate values for the time of pregnancy and parturition, if necessary by interpolations.

Results

Of 121 Asian elephants born in European zoos, twelve (9.9%) had been killed by their mothers shortly after births and seven (5.8%) had to be raised artificially, as their mothers refused them (Haufellner et al. 1993). In several cases, females showing high aggression toward their neonates learned later with assistance of keepers and "aunts" to care for their offsprings (Kock 1994). Of 426 elephants born in camps from Myanmar (Burma) and Kerala only two (0.5%) were refused by their mothers and raised by "aunts" (Nair et al. 1992; Toke Gale 1974).

Table 1. Gestation periods (days), birth weights (kg) and shoulder height (cm) of captive born Asian elephants. The numbers given for calves born in Europe correspond with numbers in the list given by Haufellner et al. (1993). Successful births are marked with *, stillbirths with SB. Animals born in the zoos of Dehiwala and Mysore are marked with [1] and twins with [T]. Sources of information: Anghi (1962); Deraniyagala (1955); Dittrich (1967, 1977); Knie (pers. com.); Kock (1994); Kock (pers. com.); Krishne Gowda (1969, 1971); Lang and Eggenberg (1991); Prins (1992); Ratnasooriya et al. (1991); Reuther (1969); Rietkerk et al. (1993); Sanderson (1907); Toke Gale (1974); Weilenmann and Isenbügel (1992).

Country	Number	sex	Birth	Gest. period	Birth weight	Shoulder height
			Modern zoo and circus:			
Europe	002	F	*	628	–	–
	003	F	SB	–	121	86
	006	F	*	668	–	–
	009	M	SB	–	138	–
	011	M	*	–	113	76
	012	F	*	658	86	83
	013	F	–	–	127	90
	014	M	*	615	50	81
	016	M	*	637	92	92
	021	F	SB	–	150	–
	022	F	SB	–	100	–
	026	F	*	–	–	85
	029	F	SB	–	101	94
	035	F	SB	646	93	85
	037	F	*	–	100	90
	038	M	*	–	124	–
	044	F	*	–	104	80
	047	F	*	659	–	–
	048	M	SB	–	141	–
	049	M	*	656	–	–
	051	M	SB	668	122	97
	052	F	*	641	106	85
	054	F	*	–	122	88
	055	F	*	614	77	81
	056	M	*	–	93	100
	061	F	*	–	78	–
	072	F	*	–	–	106
	076	M	SB	–	145	–
	092	F	*	678	142	–
	105	F	*	–	159	95
	110[T]	M	SB	682	135	–
	111[T]	M	SB	718	116	–
	114	F	*	–	90	83
	115	F	*	–	85	–
	117	M	*	–	100	–
	119	M	*	–	148	105
N. America	001	M	*	629	97	–
	003	M	*	–	82	–
	004	M	*	–	73	–
	005	F	*	–	74	–
	007	M	*	–	77	–
	008	M	*	635	102	90
	009	F	*	634	83	–

Table 1. (continued)

N. America	010	M	*	–	70	–
	011	F	*	–	109	–
	012	F	*	–	95	–
	015	F	SB	–	145	–
Japan	00X	M	SB	–	133	–
			South Asian camps:			
India	1[1]	M	SB	–	136	–
	2[1]	F	*	666	–	–
	3	M	*	663	–	–
Myanmar	1	M	*	580	–	–
	2	F	*	520	–	–
	3	–	*	510	–	–
	4	–	*	570	–	–
	5	–	*	510	–	–
	6	–	*	600	–	–
	7	F	*	660	–	–
	8	–	*	583	–	–
	9	F	*	524	–	–
	10	F	*	570	–	–
	11	M	*	630	–	–
Sri Lanka	1	F	*	637	56	76
	2	M	*	587	54	80
	3	F	*	650	54	78
	4	M	*	624	49	76
	5[1]	M	SB	619	95	84
	6[1]	M	*	648	–	82
	7	–	*	611	–	–

Of 28 reproducing females and their neonates in European zoos and circuses life histories are roughly known (Tab. 2). Females cared for by an older female when young, later accepted their offsprings significiantly more often than females lacking such affection ($chi^2_{n=\overline{1}}$ 18.52; $P \ll 0.001$). Such a significant difference could not be found between females shifted on to four times between several herds and those never shifted. Females well cared for by another female at young ages parturated more often than other females (Mann-Whitney *U* Test, $P \ll 0.01$). Females which had never been shifted, parturated more often than females which had been shifted one to four times from one to another zoo (Mann-Whitney *U* Test; $P \ll 0.01$).

Of 121 Asian elephants born in European zoos and circuses 20 (16.5%) were stillborn (Haufellner et al. 1993), but of 296 captive-bred elephants in Myanmar only 20 (4.0%) stillbirths were recorded (Toke Gale 1974). The difference between the rates of stillbirths of these different management systems is significiant ($chi^2_{n=\overline{1}}$ 18.94; $P \ll 0.001$).

Neonate weights vary between 49 and 159 kg (mean value: 100 kg. Gestation periods vary between 510 and 678 days (mean value: 618 days). There are no significant differences between male and female calves. In Asian elephants kept in zoos and circuses the mean gestation period (644 days) is significantly longer and the mean birth weight (106 kg) significantly heavier than in south Asian neonates with a mean gestation period of 598 days and a mean birth weight of 74 kg. The mean weight of stillborn calves (125 kg) is significantly higher than the mean weight of surviving neonates (92 kg). Still-

Table 2. Number and survial chances of the offsprings of 28 female Asian elephants in European zoos and the Swiss National Circus Knie. Females are distinguished according to their life histories: 1: Females which while growing up, had close contact to an older female (MT-K$^+$). 2: Females lacking this opportunity (MT-K$^-$). 3: Females which always lived in the same establishment (U 0). 4: Females which had been shifted for one to four times between zoos (U 1–4).

	MT-K$^+$ U 0	MT-K$^+$ U 1–4	MT-K$^-$ U 0	MT-K$^-$ U 1–4	Total
1. Number of females:	10	7	4	7	28
2. parturitions:	24	11	10	7	52
3. neonate accepted:	19	9	3	0	31
4. stillbirths:	4	0	1	4	9
5. neonate killed or not accepted:	1	2	6	3	12
6. losses (4. + 5.):	5	2	7	7	21
7. number of neonates per female: 6:	1	0	0	0	1
5:	1	0	1	0	2
3:	2	1	1	0	4
2:	1	2	0	0	3
1:	5	4	2	7	18

birh are produced after a significantly longer mean gestation period of 644 days than surviving neonates with a mean gestation period of 616 days (Tab. 3). There is no correlation between shoulder height of neonates and duration of gestation, but neonate weights are positively correlated with the duration of gestation (Tab. 1; Spearman rank correlation coefficient, $r_s = 0.67$; $P = 0.001$).

Since neonate weights and stillbirths correlate positively with gestation periods (Tab. 3), the chances to survive parturition can be estimated: After a gestation period of some 600 days calves are born with a mean weight of approximately 60 kg and their chance to survive parturition is practically 100%. Calves born after 650 days of gestation show mean birth weights of approximately 110 kg; their chance to survive parturition is still 70%; but calves born after a long gestation period of 680 days have a mean weight of 130 kg and a low survivial chances of approximately 20%.

According to the few available data, lenght of gestation periods and neonate weights, respectively, do not seem to correlate with ages or weights of mothers but with the relative body weights of the mother. In a small sample of seven neonate-mother pairs from Carl Hagenbeck's Tierpark in Hamburg, the swiss National Circus Knie and the Zürich Zoo, neonate weights are known as well as weights and shoulder heights of mothers. For this admittably small sample a significant negative correlation was found between relative weight of mother at the beginning of the second year of pregnancy and neonate weight. In captive Sri Lankan elephants relative weights of females in reproducing age and neonate weights are smaller (Tab. 4). The stillbirths of male twins at Port Lymphe Zoo Park, Kent, in 1990 (Nr. 110 and 111; Tab. 1) had neonate weights of 135 kg and 116 kg, respectively, and were delivered after gestation periods of 682 days and 718 days, respectively. The neonate weights and the gestation periods of these twins are above mean values of zoo-born calves. At the beginning of pregnancy their mother had a weight of 4 000 kg and short before parturition of 4 500 kg (Turkington 1991). Although she was described to be very tall (shoulder height assumed 280 cm) she had a relative weight of 14.3 to 16.0 kg/cm. As birth weight correlates positively with the frequency of stillbirths as well as the relative weight of mothers it can be concluded that high relative weight of the mother increases the probability of being stillborn.

Table 3. Weights and gestation periods of Asian elephants under different conditions of management.

	Average	Extremes max.	Extremes min.	SD	N	Mann-Withney *U* test
		Neonate weight (kg)				
1. all records:	100.1	150	49	27.7	46	
2. males:	101.5	148	49	31.5	22	
3. females:	102.3	159	54	28.3	24	$P \sim 1.00$
4. stillbirths:	124.6	150	93	20.8	13	
5. norm. births:	92.0	159	49	27.6	32	$P \ll 0.001$
6. zoo and circus:	105.6	159	50	26.6	40	
7. South Asia:	74.0	136	49	21.6	6	$P \ll 0.001$
		Gestation period (days)				
8. all records:	617.9	678	510	45.9	35	
9. males:	630.1	668	580	26.4	13	
10. females:	628.3	678	520	40.5	16	$P \sim 1.00$
11. stillbirths:	644.3	668	619	24.7	3	
12. norm. births:	615.5	678	510	37.5	32	$P = 0.15$
13. zoo and circus:	644.4	678	614	19.5	15	
14. South Asia:	598.1	666	510	51.6	20	$P \ll =0.001$

Table 4. Comparison of neonate weight with the relative weight of the mother. Relative weight (body weight in kg/shoulder height in cm) was calculated for the beginning of the second year of pregnancy. Numbers given for calves born in zoos and circuses correspond with the numbers in the list of Haufellner et al. (1993). Data on 13 Sri Lankan females at reproducing age stem from Kurt and Nettasinghe (1968) and those on five neonates from Ratnasooriya et al. (1991). For the seven mother-neonate pairs of European zoos and circuses a significant correlation between relative weight of the mother and neonate weight was found (Spearman rank correlation coefficient, $r_s = 0.94$; $P \ll 0.01$).

Nr. of neonates	birth weight (kg)	Mother weight (kg)	Mother shoulder heigt (cm)	Mother rel. weight A : B
		Zoo and circus		
105	154	3400	230	14.8
119	145	3500	280	12.5
092	142	2300	190	12.1
049	139	2600	230	11.3
096	125	2800	260	10.8
117	100	2500	230	10.9
055	77	2600	240	10.8
x ± SD	126.0 ± 28	2814 ± 460	236 ± 26	11.9 ± 1.5
		Sri Lanka		
x ± SD	61.6 ± 19 (n = 5)	2146 ± 350 (n = 13)	221 ± 12 (n = 13)	9.6 ± 1.1 (n = 13)

Discussion

The first hypothesis of this study is fully and and the second partly confirmed by the present results. Obviously, shifted females do not find adequate social contacts in the new environment and reproduce accordingly less. They may or may not adopt their newborns according to their own experience at young ages. Concerning the number of stillbirths, there are no significant differences between the four groups of females dstinguished here. Hence, the third hypothesis is confirmed: Stillbirths are not correlated with the socialization processes, however, they correlate positively with relative weight of the mother. Hence, the fourth hypothesis of this study is confirmed.

In wild-living population allo-mothers are inevitably close relatives of parturating females (Kurt 1992), but in captive ones special relationships rely mainly on behavioural characteristics of the females concerned (Garaï 1992). In intensively kept elephants in south Asia, where captive propagation is economically unimportant, hence neglected and hardly successful, "aunts" are not consired paramount social partners for parturating females (Azeez et al. 1992). But in extensively kept working elephants in south India and Myanmar the phenomenon of "aunts" is well known. Here "aunts" are allowed to follow their highly pregnant female partners to assist during parturition and for the first months or year in raising and protecting the neonate (Toke Gale 1974; Krishnamurthy 1992). In zoo and circus elephants "aunts" can play an important part in successful calf-raising (Kock 1994).

The present study shows that close special relationships between certain females correlate positively with the number of parturitions per female. Shifting single females from one zoo to another is a rather questionable practice for captive propagation of a highly social species with extreme matrilinear reproduction pattern as shown by the following sample (for details, see Haufellner et al. 1993): Four bulls in the zoos of Copenhagen, Paris, Rotterdam and Zürich mated with a total of eight females of their own group. All of these females gave birth to at least one offspring. Furthermore, the four bulls mated with at least nine females, shifted temporarily to their groups from other zoos, but only two of them gave birth to at least on offspring.

The high frequency of infanticide in western zoos and circuses is correlated with the lack of the sozialization processes. The experiences a certain female makes during neonate and juvenile ages, when looked after by an older one, later have a positive effect on its quantitative and qualitative reproductive success. In several European zoos (Haufellner et al. 1993) as well as in intensively kept populations in Kerala (Azeez et al. 1992) calves are weaned before reaching one year of age. In extensively kept working elephants such early weaning is considered to increase calf mortality (Krishnamurthy 1992). In Tamil Nadu and Thailand weaning takes place between the first and the second year (Krishnamurthy 1992; Gerbet 1994), but in Myanmar, where a relative large proportion of captive-born females reoproduce, weaning takes place only after the fourth year (Khyne U Mar 1992; Toke Gale 1974). These data from different south Asian elephant-keeping establishments advocate for the results of the present study that motherly affection received by elephants when they are young is positively correlated with later reproductive success.

Data presented in this study show that elephants in modern zoos show longer gestation periods and higher neonate weights than those born in south Asian camps. Accurate data are missing for wild-living elephants, but of five neonates born shortly after capture in the Mysore Khedda in 1967 and in one dead neonate found in 1970 in the Kakankote forests, their weights were estimated by the first author to range between 50 and 70 kg. Dittrich (1967) mentioed a 48-kg neonate of a wild south Indian female. Modern studies on population dynamics and ecology of wild-living elephants (e.g. Eisenberg und Lockhart 1972) assume average gestation periods of 22 months, but south Asian experts indicate shorter gestation periods between 17 and 22 months (overview in Toke Gale 1974; Ratnasooriya et al. 1991). From captive elephants in Asian camps as well as zoos, mating

has been reported during pregnancy (e.g. Krishne Gowda 1971; Toke Gale 1974; Ratnasooriya et al. 1991), hence actual lenght of the gestation period could have been underestimated, when the hormonal changes were not monitored (e.g. Mainka und Lothrop 1990; Taylor 1995). In Sri Lanka six reproducing females underwent continuous ethological and physiological observation, and the results indicated a shorter mean gestation period (627.5 ± 9.5 days; Ratnasooriya et al. 1991) than in zoos and circuses (644.4 ± 19.5 days).

Neonate weight is positively correlated with gestation period and relative weight of the mother. Parturating females in modern zoos and circuses can reach relative weights of 10.8 to 16.0 kg/cm, while tame Sri Lankan females in reproductive ages show a mean relative weight of 9.6 ± 1.1 kg/cm. In Tamil Nadu the mean relative weight of extensively kept females at reproductive ages is 9.2 ± 1.2 kg/cm, and it can be assumed that in wild-living ones it is even smaller (Sukumar et al. 1988).

Stillborn calves are heavier than surviving neonates and parturated after comparatively long gestation periods. One can only speculate on the gynecological reasons for stillbirths: Placentae are relatively large due to overweight of pregnant females and births take place only after the fetus can no longer be sufficiently supplied with oxygen (Naaktgeboren and Slijper 1970). In modern zoos and circuses stillbirths and infanticides are responsible for a neonate mortality of 26.5%. A high neonate mortality is also known in extensively kept elephants in Tamul Nadu: Obviously, due to premature weaning and neglect 22.5% of calves died in Tamil Nadu within the first year of live (Sukumar 1991; Krishnamurthy 1992). In wild-living populations neonate mortality is low: In a two-year study several births were observed at close range; neither stillbirth nor infanticide occured (Kurt 1992). It is reasonable to estimate that within the first five years of live in wild-living elephants mortality rates are five percent per annum in females and nine percent per annum in males (Kurt 1974, 1995 a; Sukumar 1992). These values correspond with a loss of 35% of all calves born after five years. In modern zoos and circuses about as many young elephants die within a short period before, during and after parturition.

The findings of this study suggest the following management practices in zoos: (1) Young females should grow up in the company of at least one motherly older female. (2) Females should be kept in such numbers that special relationships can be established. (3) Shifting single females for breeding reasons between zoos destroys established special relationships and reduces the reproductive potential of a female. A transfered female should always be accompanied by another female, with which it has already established a special relationship. (4) As stillbirths correlate positively with overweight of mothers, the causes of overweight should be ruled out by changing the feeding practices and allowing captive elephants more movement.

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Zusammenfassung

Neonatensterblichkeit bei asiatischen Elefanten in Menschenobhut

Ein Drittel aller asiatischen Elefanten, die in europäischen Zoos und Zirkussen zur Welt kamen, wurden tot geboren bzw. von ihrer Mutter kurz nach der Geburt getötet oder zumindest nicht aufgenom-

men. Bei wildlebenden oder in Südostasien extensiv gehaltenen Arbeitselefanten sind Totgeburten und Kindstötungen selten. Kindstötung hängt zusammen mit der Lebensgeschichte der Mutter: Weibchen, die in Gesellschaft eines älteren mütterlichen Weibchens aufwuchsen, nahmen ihre Jungen in der Regel problemlos an. Jene, die nicht entsprechend umsorgt wurden, zeigten die Tendenz zur Kindstötung oder wenigstens zur Verweigerung des Neugeborenen. Totgeborene Kälber haben höhere Gewichte (124,6 ± 20,8 kg) als überlebende Kälber (92,0 ± 27,6 kg). Positive Korrelationen wurden gefunden zwischen Tragzeit und Neonatengewicht und zwischen Neonatengewicht und relativem Gewicht (Körpergewicht/Schulterhöhe) der Mutter. Da Elefantinnen in modernen Zoos und Zirkussen relativ schwerer sind als in südasiatischen Elefantencamps, bringen sie ihre Kälber nach längerer Tragzeit (644,4 ± 19,5 Tage) und mit höheren Geburtsgewichten (105,6 ± 26,6 kg) zur Welt, als die extensiv gehaltenen Elefantinnen in Südasien (598,1 ± 51,6 Tage; bzw. 74,0 ± 21,6 kg). Die Überlebenschancen bei der Geburt sind negativ korreliert mit der Tragzeitlänge und dem Neonatengewicht.

References

Anghi, C. G. v. (1962): Breeding Indian elephants, *Elephas maximus*, at the Budapest Zoo. Int. Zoo Yb. **4**, 83–86.

Azeez, M. A.; Unnikrishnan, M. D.; Raghavan, I. K.; Menon, T. G. (1992): Insurance coverage to elephant. In: The Asian elephant; ecology, biology, diseases and management. Ed. by E. G. Silas, M. Krishna Nair, and G. Nirmalan. Trichur: Lumiere Printing Work. Pp. 127–129.

Benedict, F. G. (1936): The physiology of the elephant. Washington: Carnegie Institution.

Deraniyagala, P. E. P. (1955): Some extinct elephants, their relatives and the two living species. Colombo: Government Press.

Dittrich, L. (1967): Beiträge zur Fortpflanzung und Jugendentwicklung des Indischen Elefanten, *Elephas maximus*, in Gefangenschaft mit einer Übersicht über die Elefantengeburten in europäischen Zoos und Zirkussen. Zool. Garten (NF) **34**, 56–92.

Dittrich, L. (1977): Über die Nachzucht des Asiatischen Elefanten (*Elephas maximus*) in europäischen Tiergärten. Zool. Garten (NF) **47**, 296–302.

Eisenberg, J. F.; Lockhart, M. (1972): An ecological reconnaissance of Wilpattu National Park, Ceylon. Smithonian Contribution to zoology **101**, 1–118.

Gerbet, S. (1994): L'Elephant de travail en Thailand. Nantes: Ecole nationale véterinaire.

Garaï, M. E. (1992): Special relationships between female Asian elephants, *Elephas maximus*, in zoological gardens. Ethology **90**, 197–205.

Haufellner, A.; Kurt, F.; Schilfarth, J.; Schweiger, G. (1993): Elefanten in Zoo und Zirkus, Dokumentation Teil 1. München: Karl Wenschow.

Khyne U Mar (1992): Development of artificial insemination in Myanmar elephants (*Elephas maximus*). Forestry Science Research Paper. Yangon: Ministry of Forestry.

Kock, K. (1994): Elefanten – mein Leben. Hamburg, Zürich: Rasch und Röhring.

Krishnamurthy, V. (1992): Care and management of elephant calves in captivity. In: The Asian elephant; ecology, biology, diseases and management. Ed. by E. G. Silas, M. Krishna Nair, and G. Nirmalan. Trichur: Lumiere Printing Work. Pp. 82–85.

Krishne Gowda, C. D. (1969): A brief note on breeding Indian elephants, *Elephas maximus*, at Mysore Zoo. Int. Zoo Yb. **9**, 99.

Krishne Gowda, C. D. (1971): Breeding Indian elephants, *Elephas maximus*, at Mysore Zoo. Int. Zoo Yb. **12**, 121–122.

Kurt, F. (1974): Remarks on the social structure and ecology of the Ceylon elephant in the Yala National Park. In: The behaviour of ungulates and its relation to management. Ed. by V. Geist and F. Walter. Morges: IUCN Publ. new ser. **24**, 618–634.

Kurt, F. (1992): Das Elefantenbuch. Hamburg, Zürich: Rasch und Röhring.

Kurt, F. (1995 a): Asian elephants (*Elephas maximus*) in captivity and the role of captive propagation for maintenance of the species. In: Proceedings of the Eighth U. K. Elephant Workshop. Ed. by N. G. Spooner and J. A. Whitear. Southhampton: North of England Zool. Soc. Pp. 69–96.

Kurt, F. (1995 b): The preservation of Asian elephants in human care – a comparison between different keeping systems in South Asia and Europe. Animal Research and Development **41**, 38–60.

Kurt, F.; Nettasinghe, A. P. W (1968): Estimation of body weight of the Ceylon elephant (*Elephas maximus*). Ceylon vet. J. **16**, 24–26.

Lang, E. M.; Eggenberg, U. (1991): Protokoll einer Elefantengeburt. Zool. Garten (NF) **61**, 5–7.
Mainka, S. A.; Lothrop, C. D. (1990): Reproductive and hormonal chances during the oestrus cycle and pregnancy in Asian elephants (*Elephas maximus*). Zoo Biology **9**, 411–419.
Naaktgeboren, C.; Slijper, E. J. (1970): Biologie der Geburt. Hamburg, Berlin: Paul Parey.
Nair, G. P.; Radhakrishnan, K.; Chandrasekharan, K. (1992): Mating behaviour of the Asian elephant in captivity. In: The Asian elephant; ecology, biology, diseases and management. Ed. by E. G. Silas, M. Krishna Nair, and G. Nirmalan. Trichur: Lumiere Printing Work. Pp. 78–81.
Poole, J. H. (1989): Mate guarding, reproductive success and female choice in African elephants. Animal Behav. **37**, 842–849.
Prins, P. J. (1992): Op goed geluk – de geboorte van een zondagskind. Zoo Informatie Emmen **1**, 1–32.
Ratnasooriya, W. D.; Fernando, S. B. U.; Manatunga, A. M. V. R. (1991): Pregnancy duration of Sri Lankan elephant (*Elephas maximus maximus*) in captivity. Med. Sci. Res. **19**, 623–624.
Reuther, R. T. (1969): Growth and diet of young elephants in captivity. Int. Zoo Yb. **9**, 168–179.
Rietkerk, F. E.; Hidding, H.; Van Dijk, S. (1993): Hand-rearing an Asian elephant, *Elephas maximus*, at the Noorder Zoo, Emmen. Int. Zoo Yb. **32**, 244–252.
Sanderson, G. P. (1907): Thirteen years among the wild beasts of India. Edingburgh: John Grant.
Sukumar, R. (1991): The breeding and management of captive Asian elephants. In: Proceedings of the fifth U. K. elephant workshop. Ed. by N. G. Spooner. Windsor. Pp. 40–49.
Sukumar, R. (1992): The Asian elephant – Ecology and management. Cambridge Univ. Press.
Sukumar, R.; Joshi, N. V.; Krishnamurthy, V. (1988): Growth in Asian elephant. Indian Acad. Sci. (Animal Sci.) **97**, 561–571.
Taylor, V. (1995): The social behaviour and breeding physiology of a group of captive Asian elephants. In: Proceedings of the Eighth U. K. Elephant Workshop. Ed. by N. G. Spooner and J. A. Whitear. Southhampton: North of England Zool. Soc. Pp. 58–68.
Toke Gale (1974): Burmese timber elephants. Rangoon: Trade cooperation.
Turkington, J. (1991): Asian elephant pregnancy and birth at Porth Lymphe. In: Proceedings of the fifth U. K. elephant workshop. Ed. by N. G. Spooner. Windsor. Pp. 37–39.
Weilenmann, P.; Isenbügel, E. (1992): Keeping and breeding the Asian elephant at Zurich Zoo. In: The Asian elephant; ecology, biology, diseases and management. Ed. by E. G. Silas, M. Krishna Nair, and G. Nirmalan. Trichur: Lumiere Printing Work. Pp. 78–81.

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